The Efficiency For Education Using Data Envelopment Analysis

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***Abstract*—Universities perform an important role in the development countries due to their capacity for providing critically needed education and innovation. Education is critical to our development as individuals, societies; it helps to a successful and productive future. Data envelopment analysis (DEA) has been applied to evaluate the relative efficiencies among universities and relative efficiencies among university departments or courses. The purpose of this study is to compare between males and females relative efficiency in public universities. The fifteen Egyptian public universities are used to evaluate the performance for Egyptian meals and females for academic year 2013/2014. Two DEA models which used to evaluate the performance for Egyptian meals and females are; constant returns to scale (CRS) and variable returns to scale (VRS). The numbers of Enrolled used as inputs, and the numbers of Graduates Students, and Obtaining a Ph.D were used as outputs. The percentage of efficiency was determined for females 26.7% by CRS, 60% by VRS, but the percentage of efficiency for males 13.3% by CRS, 53.3% by VRS for fifteen Egyptian public universities. Tobit regression used as second stage for this study to determine the most environmental factors that affecting the efficiency of the gender.**

Keywords—Data envelopment analysis, CRS& VRS models, relative efficiency, Tobit regression.

1- INTRODUCTION

Egypt has the largest overall education system in the Middle East and North Africa and it has grown rapidly since the early 1990s. In recent years the Government of Egypt has accorded even greater priority in improving the education system. Understanding how teaching and research contribute to the overall efficiency of university operations is of great importance for universities to improve their performance

The higher education topics receiving considerable attention in policy circles and within academe today are productivity and efficiency. As enrollments in higher education continue to expand, public funding is becoming increasingly scarce, particularly as competition increases from other recipients of public funds such as healthcare and corrections. In light of this many policymakers have found themselves asking if higher education institutions are using their resources productively. Over the past decade, questions of this kind have given rise to a number of studies seeking to assess productive and cost efficiency.

Several studies in the literature exist on the use of DEA for evaluating the efficiency of universities and university departments. In recent years, several studies have undertaken analysis of efficiency of public universities using DEA methodology. McMillan and Datta (1998) used DEA to estimate the efficiency of 45 Canadian universities in 1992- 93. The data they used came from the Canadian Association of University Business Officers (CAUBO) and the Association of Universities and Colleges of Canada (AUCC). A series of 9 DEA models was estimated, three of which examined cost efficiency. The models were formulated using different combinations of the aggregate input and output measures they specified. This was done in order to evaluate the sensitivity of their findings [1]. Afonso and Aubyn (2005) analyzed the efficiency of expenditure in education provision among the educational systems of 25 countries with DEA. By regressing DEA output scores on non-discretionary variables, both using Tobit and a single and double bootstrap procedure, they find that inefficiency is strongly related to GDP per head and adult educational attainment [2]. Aubyn et al. (2008) studied by comparing used resources with education and research outputs and outcomes in the EU Member States are. Efficiency in public tertiary education systems across EU countries plus Japan and the US is assessed with semi-parametric methods and stochastic frontier analysis [3]. Toth (2009) use DEA to compare the efficiency of higher education systems. The study examines whether their efficiency is influenced by the extent of the contribution of the state and the private sector or socio-economic factors like GDP per capita and education level of parents [4]. McDonald (2009) examines second stage DEA efficiency analyses, within the context of a censoring data generating process (DGP) and a fractional data DGP[5] . Kempkes and Pohl (2010), analyze the efficiency of 72 public German universities for the years 1998-2003, applying data envelopment analysis and stochastic frontier analysis. Contrary to earlier studies they account for the faculty composition of universities, which proves to be an essential element in the efficiency of higher education. Their main finding is that East German universities have performed better in total factor productivity change compared to those in West Germany [6] . Daghbashyan (2011) investigates the economic efficiency of higher education institutions (HEI) in Sweden to determine the factors that cause efficiency differences. Stochastic frontier analysis is utilized to estimate the economic efficiency of 30 HEI using both pooled and panel data approaches [7]. Wolszczak-Derlacz and Parteka (2011) analyze the efficiency of 259 public HEIs from 7 European countries (Austria, Finland, Germany, Italy, Poland, Switzerland, United Kingdom) over the years 2001-2005, using two-stage DEA (DEA and bootstrapped truncated regression). Their results indicate that a higher share of funds from external sources and a higher number of women among academic staff improve the efficiency of the HEIs [8] .Sibel Selim and Sibel Aybarç Bursalıoğlu (2015) use a two- stage data envelopment analysis for 51 public universities in Turkey in 2006-2010. The first stage is concerned with data envelopment analysis to measure the bootstrapped efficiency of the universities. This is followed by factors that affect the efficiency of the universities random effects Tobit model in the second stage. [9]. Pavla and Mikusova (2015) used DEA to evaluate the technical efficiency for Czech public HEIs from 2013 and determined the following variables: the academic staff and other costs as inputs and the bachelor and master's graduates and students, Ph.D graduates and students as output [10]. Ismail, A. R. (2015) provides an introduction to DEA and some important methodological extensions that have improved its effectiveness as a productivity analysis tool. Data Envelopment Analysis (DEA) techniques are used to estimate technical and scale efficiency of individual Saudi Arabia universities 2010. The purpose of this paper is to present basic principles of DEA and evaluate its application possibilities to assess the performance of nineteen Saudi Arabia universities. DEA is a choice between constant returns to scale CRS and variable returns to scale VRS. The CRS efficiency score represents technical efficiency, which measures inefficiencies due to input/output configuration and as well as size of operations. [11]. Ismail, A. R. (2015) used DEA models under the assumptions of Constant Returns to Scale (CRS), and Variable Returns to Scale (VRS) models to estimate efficiency scores of the different university . The study used the Tobit regression [12]. Suirbu A. et al.(2016) used data envelopment analysis (DEA) to measure the relative efficiency of academic departments of the faculty of Economics. Input and output criteria are determined and measured utilizing the academic stuff performance measurement scheme of the departments of the State Agrarian University of Moldova. Twelve input and two outputs which strongly influence the efficiency of the academic departments were selected[13]. Pietrzak M. et al.(2016)discussed the problem of defining and measuring efficiency in the case of publicly held HEIs with particular emphasis put on the Data Envelopment Analysis (DEA) method. Secondly, they present the results of our empirical investigation of efficiency assessed using the DEA method conducted on the sample of 33 Poland faculties specialized in social sciences. They used Charnes-Cooper-Rhodes (CCR) output oriented model with two inputs and three outputs. Next, we present some important differences in efficiency of those faculties. They also define benchmarks for inefficient HEIs and quantify the gaps to be fulfilled by them in order to become efficient [14]. Fahad Mohammed Alabdulmenem (2017) used data envelopment analysis (DEA) to measure the relative efficiency of 25 public universities in Saudi Arabia. Results show that although most public universities in the country are efficient, some fall behind in performance due to poor utilization of available resources. Implications of this are discussed and recommendations are provided [15].

2- Data Envelopment Analysis and Models

Institutions subject to evaluation in the DEA literature are called Decision Making Units (DMUs), such as, the universities, the hospitals, nursing homes, group practices, and other facilities that are evaluated for performance using DEA. In late 1970s the data envelopment analysis was introduced by Charnes and Cooper as a method to identify the relative efficiency of the cooperating decision making units (DMU), in fact the discussion started in 1978 in a PhD dissertation by Rhodes. DEA determines the efficiencies of individual DMUs within a group relative to the other DMUs in the group, the most efficient DMUs constitute the efficient frontier of the group, relative to which the efficiencies of the remaining DMUs are measured. The frontier is non-parametric, i.e. no functional form needs to be specified, in contrast to stochastic production frontiers (SPF) [16]. DEA overcomes this problem by allowing each DMU to choose the vectors of the input and output weights, which maximize its own ratio of weighted output to weighted input, subject to the constraint that the weight vectors chosen by the *ith* DMU should not allow any DMU to achieve a ratio of weighted output to weighted input in excess of unity.

The first measure of technical efficiency was proposed by Debreu, 1951, despite the theoretical relevance of this study, efficiency was not quantified in it. This task was undertaken by Farrell, 1957, who considered the pioneer in the measurement of technical efficiency as he measured the efficiency of agricultural production in the United States. Farrell proposed that the efficiency consists of two components: technical efficiency, which reflects the ability to obtain maximal output from a given set of inputs. A combination of technical and locative efficiency yields a measure of total economic. The efficiency score in the presence of multiple input and output factors is defined as:

$$DEA\ efficiency = \frac{weighted\ sum\ of\ outputs}{weighted\ sum\ of\ inputs} \quad (1)$$

Assuming that there are *n* DMUs, each with *m* inputs and *s* outputs, the relative efficiency score of a test DMUs is obtained by solving the following model proposed by [17]:

$$Maimize \quad \frac{\sum_{k=1}^{s} v_k Y_{kp}}{\sum_{j=1}^{m} u_j X_{jp}}$$

$$subject\ to \quad \frac{\sum_{k=1}^{s} v_k Y_{ki}}{\sum_{i=1}^{n} u_j X_{ji}} \le 1; \quad \forall i \quad (2)$$

$$v_k, u_j \ge 0 \quad \forall k, j.$$

Where
p= the decision making unit being evaluated in the set of *i* = 1, 2, …, *n* decision making units
k = 1 to s,
j = 1 to m,
i = 1 to n,
y_{ki} = amount of output k produced by DMU i,
x_{ji} = amount of input j utilized by DMU i,
v_k= weight given to output k,
u_j = weight given to input j.
s = the number of services or outputs produced by the DMUs

The fractional program shown as (2) can be transferred to a linear program as shown in (3). For more details on model development, see [17].

$$Maimize \quad \sum_{k=1}^{s} v_k Y_{kp}$$

$$subject\ to \quad \sum_{j=1}^{m} u_j X_{jp} = 1;$$

$$\sum_{k=1}^{s} v_k Y_{ki} - \sum_{j=1}^{m} u_j X_{ji} \le 0 \quad (3)$$

$$v_k, u_j \ge 0 \quad \forall k, j.$$

According to the assumptions relating the change in outputs as a result of the change in inputs, the DEA model can be classified as having either constant return to scale (CRS) or variable returns to scale (VRS). Under CRS models the outputs are not affected by the size of the DMU, rather they change in direct proportion to the change in inputs assuming that the scale of operation does not influence efficiency; therefore, in the CRS models the output and input oriented measures of efficiency are equal. Under VRS models, changes in outputs are not necessarily proportional to the changes in the inputs; therefore In the VRS models the output and input oriented measures of efficiency scores are not equal for inefficient units. The output oriented VRS model as follows:

$$Max\ \phi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum s_r^+\right)$$

$$Subject\ to$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0} \quad i = 1,2,\ldots,m; \quad (4)$$

$$\sum \lambda_j y_{rj} - s_r^+ = \phi y_{r0} \quad r = 1,2,..s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \ge 0 \quad j = 1.2,\ldots,n.$$

The CRS model is designed with the assumption of constant returns to scale. This means that there is no assumption that any positive or negative economies of scale exist. It is assumed is that a small unit should be able to operate as efficiently as a large one – that is, constant returns to scale. In order to address this, Banker, Charnes, and Cooper developed the BCC model. It is also referred as VRS model. The VRS model is closely related to the standard CRS model as is evident in the dual of the BCC model.

The above problem is run *n* times in identifying the relative efficiency scores of all the DMUs. Each DMU selects input and output weights that maximize its efficiency score. In general, a DMU is considered to be efficient if it obtains a score of 1 and a score of less than 1 implies that it is inefficient [20]. This is followed by factors that affect the efficiency of the gender random effects panel Tobit model in the second stage. The model of interest is formulated as follows: the dependent variable is y_i represents the efficiency score of the gender for universities *i*, the model can be written as,

$$y_{it}^* = \beta x_{it} + u_{it} \quad i = 1,2,\ldots,N \quad t = 1,2,\ldots,T \quad (5)$$

$$u_{it} = v_i + \varepsilon_{it}$$

where the observed variables is:

$$y_{it} = \begin{cases} y_{it}^{*} & if \quad y_{it}^{*} > 0 \\ 0 & otherwise \end{cases} \qquad (6)$$

and

y^* is a T x 1 vector of observations on the dependent variable

x a T x k matrix of observations on the explanatory variables

β is a k x 1 vector of parameters

ε is a T x 1 vector of error terms for T observations

3-APPLICATION

Universities can be defined as institutions offering education and training, conducting scientific research and publishing such studies. Gender differences in cognitive, social, and personal characteristics have been investigated, research has identified differences in several specific cognitive skills as well as in a range of social and personal characteristics. Some differences are apparent from infancy; others do not emerge until late childhood or adolescence. Interestingly, in several skills the differences between boys and girls have shrunk over the last two to three decades. This indicates that socialization and differential experiences play roles in gender differences. Even when gender differences are significant and consistent over time, we still do not fully understand why they exist. Different experiences and socialization are almost certainly involved, but biological factors may also have important effects.

This research aims to measuring the relative efficiency between males and females of the output for education, in the fifteen of Egyptian public universities. The data envelopment analysis method in assessing the relative efficiency of fifteen for the Egyptian Governmental Universities employed. The numbers of Enrolled used as inputs, and the numbers of Graduates Students, and Obtaining Ph.D were used as outputs. The academic year (2013-2014) is used. The data was taken from STATISTICAL YEARBOOK September Issue 2015.

Two DEA models were used and CRS, VRS models are running. The efficiency scores of fifteen Egyptian Governmental Universities were calculated for males and females, the two models as seen in table (1)

Online Software (DEAOS) was used to estimate technical efficiency scores of males and females for the Egyptian Governmental .It was available on: www.deaos.com

Table (1) DEA efficiency scores for the two models

University (DMU)	Model 1 (output oriented efficiency) For males		Model 2 (output oriented efficiency) For females	
	CRS	VRS	CRS	VRS
Cairo	0.733	1	0.955	1
Alexandria	0.938	1	0.808	0.984
Ain Shams	0.866	1	0.975	1
Asyout	0.928	0.938	1	1
Tanta	0.789	0.791	1	1
El Mansura	0.953	0.966	0.862	0.922
El Zagazig	1	1	0.769	0.81
El Menia	0.981	1	0.74	0.827
El Menoufia	0.989	0.996	1	1
Suez Canal	0.80	0.92	0.608	1
Ganoub el Wadi	0.675	0.694	0.698	0.822
Helwan	0.864	0.894	1	1
Al-Azhar	0.62	1	0.546	0.744
Fayoum	1	1	0.667	1
Beni –suef	0.988	1	0.769	1

Table (1) observes that the eight Egyptian Governmental Universities are fully efficient according to VRS while the number of efficient DMUs was two units according to CRS for the first model (male). In the second model (female) nine Egyptian Governmental Universities are fully efficient according to VRS while the number of efficient DMUs was four units according to CRS. The percentage of efficiency was determined for females 26.7% by CRS, 60% by VRS, but the percentage of efficiency for males 13.3% by CRS, 53.3% by VRS for fifteen Egyptian public universities.

Table (2) summary for DEA efficiency scores for the two model

	Model 1 (output oriented efficiency) For males		Model 2 (output oriented efficiency) For females	
	CRS	VRS	CRS	VRS
Mean	0.8749	0.9526	0.8265	0.9426
Standard Deviation	0.1252	0.0907	0.1565	0.0869
Minimum	0.6200	0.6940	0.5460	0.7740
Maximum	1	1	1	1

But although relative high percentage of efficient units there is wide variation in efficiency score and a big gap between lower and higher efficiency score. In model 1 for male Al-Azhar University have the lower efficiency score in CRS model, and Ganoub el Wadi Ganoub el Wadi have the lower efficiency score for male in VRS model. In model 2 for female Al-Azhar University have the lower efficiency score in CRS and VRS models. Table (2) showed statistical summary for DEA efficiency scores.

4-The second stage

Data envelopment analysis (DEA) is a technique widely used to evaluate the relative efficiency of individual decision-making units (DMUs). DEA efficiency scores are typically defined on the interval] 0,1], with, in general, few values, if any, close to 0 but some values of unity. In order to examine the effect on the efficiency of DMUs of factors that are beyond their control, often in a second stage, a regression model is estimated for DEA scores.

In this study two stage efficiency analyses are applied. The first stage the study was estimated DEA models under the assumptions of Constant Returns to Scale (CRS), and Variable Returns to Scale (VRS). Online Software (DEAOS) was used to calculate the technical efficiency scores of gender for public Egyptian university. The second stage determined the causes of technical inefficiency using the Tobit Regression Analysis. Tobit regression model is a statistical non-linear model proposed by James Tobin to describe the relationship between a non-negative dependent variable y_i and an independent variable x_i . The word Tobit is taken from the name Tob and "it" is added to it (Yustin I. Bangi 2014). Tobit model was first suggested in econometrics literature by Tobin 1958. These models are also known as truncated or censored regression models where expected errors are not equal zero. Therefore, estimation with an Ordinary Least Squares (OLS) regression would lead to a biased parameter estimate since OLS assumes a normal distribution of the disturbance and the dependent variable. To facilitate the Tobit framework, the dependent variable used technical inefficiency rather than technical efficiency. Technical inefficiency was calculated by subtracting the technical efficiency scores. The regression model was taken the form (5) and (6).

Table (3) normalized coefficients from Tobit regression analysis

Coefficient	Coefficients for model (1) male		Coefficients for Model (2) females	
	CRS	VRS	CRS	VRS
Graduates Students	−0.000153946^{ns} 0.000270660)	−3.33326e-05^{ns} (7.75506e-05)	−0.000154981^{ns} (0.000172123)	−0.000190459** (7.48756e-05)
Obtaining Ph.D	0.00471500^{ns} (0.0179596)	0.00974177^{ns} (0.00617500)	0.00650757 ^{ns} (0.00940023)	0.0104382** (0.00409403)

Tobit analysis using the technical inefficiency from the number of of Enrolled used as inputs, and the numbers of Graduates Students, and Obtaining a PhD were used as outputs. We find that the relationship between the relative efficiency and the number of graduates is inverse relationship in the two models (CRS and VRS) for males and females. While the relationship between the relative efficiency and the number Obtaining Ph.D is a positive weak where they are distinguished both for males or females.**Significant at the 5%level of significance. The (ns) is not significant at the 5%level of significance. The numbers between brackets are the associated standard errors.

5- Conclusion

The objective of this paper is to compare between the estimate relative efficiency for the male and estimate relative efficiency for female in fifteen Egyptian public universities 2013 /2014. Data envelopment analysis (DEA) techniques are used to estimate technical and scale sufficiency of male and female (the gender) as a first step. The study uses the Tobit regression to determine the most environmental factors that affecting the efficiency of this institute. The numbers of Enrolled used as inputs, and the numbers of Graduates Students, and Obtaining a Ph.D were used as outputs. Two DEA models which used to compare between the estimate relative efficiency for Egyptian meals and females are; constant returns to scale (CRS) and variable returns to scale (VRS). The percentage of efficiency was determined for females 26.7% by CRS, 60% by VRS, but the percentage of efficiency for males 13.3% by CRS, 53.3% by VRS for fifteen Egyptian public universities. The result shows that the relative efficiency of the female is higher than the relative efficiency of the male when the two DEA models CRS and VRS are used.

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